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THE CORROSIVE ACTION OF CERTAIN BRINES IN MANITOBA[1]

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The brines geologically considered.—The Manitoban escarpment consists of a range of hills which fringes on the western side the lake system of which Cedar Lake, Red Deer Lake, Lake Winnipegosis and Lake Manitoba are the most important members, and extends southward beyond the international boundary line into North Dakota. It reaches, in the Porcupine Mountain, a maximum elevation of 2,500 feet above sea-level. At the foot of the escarpment the plain slopes gently eastward from an elevation of 900 feet to one of 700 feet. The escarpment is the eastern edge of the Cretaceous shales which extend throughout the western prairies. The shales were uplifted in early Tertiary times, and were eroded from the Red River valley back to the escarpment before the end of the Tertiary period. On this surface of erosion limestones of Paleozoic age are exposed, Ordovician, Silurian, and Devonian strata appearing successively from the edge of the pre-Cambrian shield to the escarpment; while the Dakota sandstone—the lowest member of the Cretaceous series—rests directly on the surface of the Devonian limestones. The basin of the lake system has been carved from Devonian limestones and dolomites.

At the foot of the escarpment, on the west side of the lakes, a series of salt springs emerges from middle and upper Devonian strata (the Winnipegosan dolomite and Manitoban limestone respectively).[2] These springs follow the base of the escarpment for a distance of 250 miles, but are found in greatest numbers on the west shore of Dawson Bay, at the north end of Lake

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[1] Published with the permission of the Directing Geologist, Geological Survey of Canada.

[2] R. C. Wallace, "Gypsum and Brines in Manitoba," *Memoir Geol. Surv. Canada* (in press).

Winnipegosis. Around the springs are flats, absolutely devoid of vegetation, from a half-acre, as the case may be, to several hundred acres in extent. These the traveler may quite unexpectedly find in the midst of a dense forest; but the majority of the springs are to be found in close proximity to river or lake.

The brines are not confined to a single geological horizon. They appear in both the Winnipegosan dolomite and Manitoban limestone, the combined thickness of which is approximately 250 feet. Owing to the comparatively level surface and the appreciable dip of the strata toward the west, the difference in elevation between the various springs is very small—not more than 50 feet. The springs may consequently be referred with greater exactness to a contour horizon than to any geological horizon.

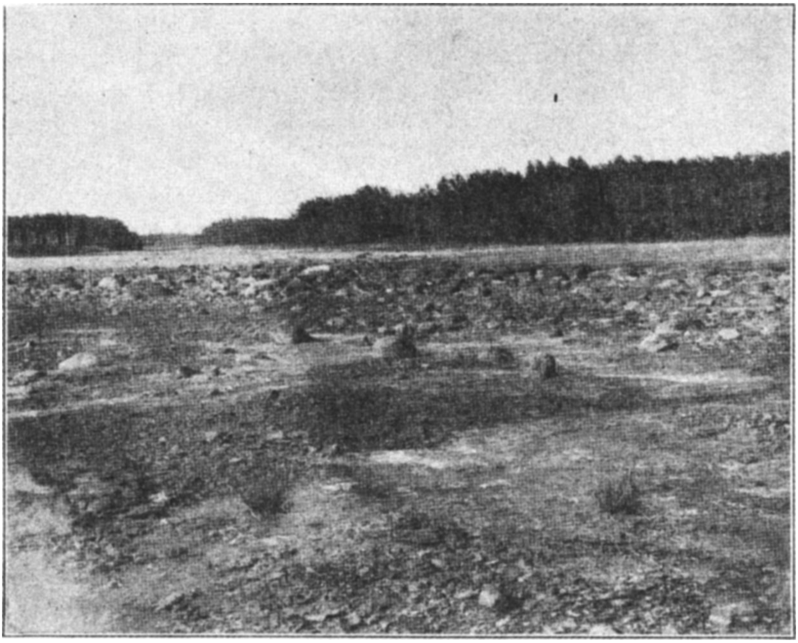

FIG. 1—Bowlder-strewn salt flat, Geikie's Creek, Sagemace Bay, Lake Winnepegosis

The Dakota sandstone, which directly overlies the comparatively porous Devonian strata, is a well-known water-bearing horizon in the middle northwestern states and in the western provinces. It is capped by impervious shales, and the water, which circulates under considerable hydrostatic pressure, apparently penetrates laterally into Devonian strata, leaches sodium chloride from certain horizons in which the salt has been precipitated with the limestone, and reaches the surface where the covering of drift is thin or absent. On an average approximately 430 gallons of brine reach the surface per minute during the dry season; and the salt, if evaporated, would cover the main salt area (200 miles by 30 miles) with a coating 2 feet thick in 10,000 years.

TABLE I

	Brine*	Sea-Water†		Brine*	Sea-Water†
K	1.37	1.11	HCO_3	0.20	...
Na	34.99	30.59	Cl	55.95	55.29
Ca	2.02	1.20	Br	0.04	0.19
Mg	0.55	3.73	I	Nil	...
Fe	...	...	Si	0.03	...
Al	0.01	...	Percentage salinity	7.29	3.30 to 3.74
SO_4	4.88	7.69			
CO_3	Nil	0.21			

* From Salt Creek, Salt Point Peninsula, Lake Winnipegosis. Professor M. A. Parker, analyst.

† Mean of 77 analyses by W. Dittmar.

Composition of the brines.—Numerous analyses have been made of the brines. The composition is remarkably uniform, differences occurring only when the brines pass through a considerable depth of glacial drift before reaching the surface. In this case the percentage of Ca and SO_4 ions is considerably greater than normal. Table I gives the analyses of a typical brine, Dittmar's average of 77 analyses of sea-water being given for comparison.

The analyses are given in percentages of total solids. The percentage of salinity in the analysis quoted is somewhat greater than normal, but the percentage values for the constituents vary only slightly from the figures quoted. While on the whole the brine is very similar to sea-water, it is a distinctly purer solution of sodium chloride. The relative percentages of Ca and Mg ions differ in a sense, which may be accounted for by the abstraction of Ca ions by marine organisms. The apparent differences in the carbonate values are due to the fact that in the statement of the analysis of sea-water the total carbonate is reckoned as normal carbonate. The concentration of the brine is, however, notably higher than that of sea-water.

Action on the bowlders.—The glacial drift was to a large extent derived from the pre-Cambrian areas in the north. The bowlders which cover the bare flats where the salt springs are found are mainly gneissose or granitic, though occasionally dark-green epidiorites or Paleozoic limestones are seen. Chemical solution has taken place on an extensive scale, many bowlders having been reduced on every side by at least a foot. This is very clearly seen in the salt creeks in which the water is carried from the springs to the lake, the bowlders standing on a much-eroded base, like the rocks of a great sand desert. On the flats the bowlders are pitted into very fantastic forms, the ferromagnesian minerals having suffered to the greatest extent. Not even quartz nor garnet has escaped the action of the solvent. Gneissose structures are accentuated by differential weathering, garnetiferous bands standing out in special relief. As the corrosive power of the brine is apparently much more intense than that of sea-water, it is of interest to inquire into the processes involved in the disintegration of the rock.

Chemical processes.—Regarded as a chemical agent, the brine may be considered to be a weak solution of sodium chloride. A considerable amount of experimental work has been done on the action of solutions of sodium chloride on minerals, but the evidence is somewhat conflicting.[1] Joly has, however, proved that sodium chloride, in the presence of the atmosphere, is a more active disintegrating agent than pure water. Daubree's experiments were conducted under somewhat different conditions. In the case of the brines physical conditions have been favorable. Normally the salt crystallized in thin crusts at the base of the bowlders. The salt is somewhat deliquescent, and gradually extends upward over the side of the bowlder, till a thin coating of brine, somewhat diluted during the process, covers the whole bowlder. The conditions are thus most favorable for chemical activity in presence of the atmosphere; and the writer believes that it is primarily as an agent for distributing the liquid in a thin film over the bowlder, and only secondarily as a direct chemical agent, that the dissolved material in the brine acts in the process of disintegrating the bowlder. It has been proved conclusively that water is itself an agent of considerable chemical power and that it acts most vigorously as a corrosive agent when in intimate contact with the atmosphere, as, for instance, at a water surface.

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[1] Daubree, *Synthetische Studien zur Experimentalgeologie*, 1880, 205; Thoulet, *Compt. Rendu*, CX, (1890), 652; Joly, *Proc. Roy. Irish Acad.*, XXIV (1902).

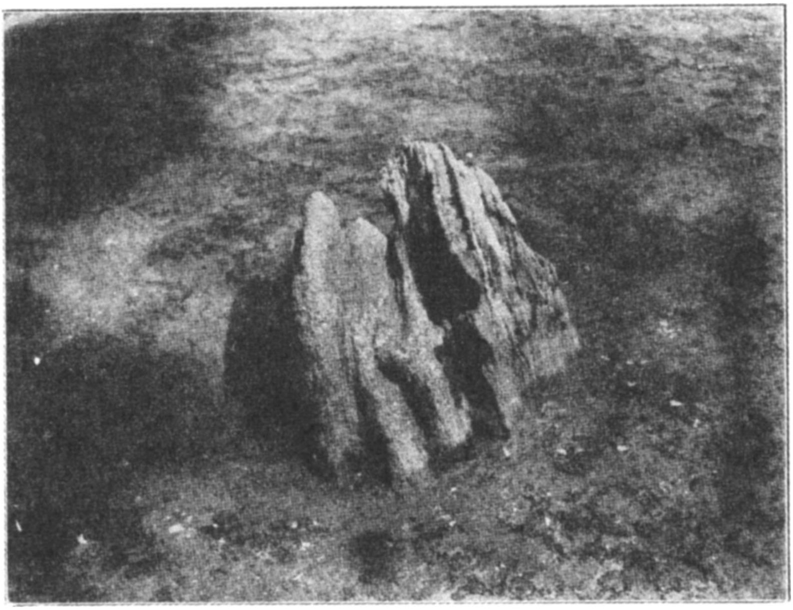

FIG. 2.—Corroded bowlder, salt flat, Pelican Bay, Lake Winnipegosis

The actual process of disintegration is necessarily different for different minerals. The ferromagnesians, more particularly the amphiboles and pyroxenes, have suffered to a greater extent than the feldspars. The alkaline earths are somewhat readily attacked and dissolved as carbonates or chlorides, and silica with alumina, mixed or combined, is left in colloidal form. The percentage of soluble material in the case of the feldspars is correspondingly smaller. To some extent, with the metasilicates at least, the process is one of hydrolysis; and while it may be effected by water alone, it is doubtless hastened by the carbon dioxide of the atmosphere. The gels which are formed during the process of decomposition are irreversible—that is, they cannot, by the action of electrolytes, pass over into sols and be in this way removed from the sphere of action. They exercise, however, a selective absorption, alkalies being removed from the brine while the acid radicals remain in solution. With potassium salts in particular this property of the colloids of the soils is of importance in retaining the valuable ingredients of fertilizers. This selective absorption tends, therefore, to hydrolyze the chloride, and to render the solution more acid. The free acid reacts on the partially decomposed minerals, causing further disintegration. Quartz is not affected thereby, but the corrosion of quartz is in all probability due to the action of alkaline carbonates.

In short, then, the principal fact in the disintegration is the intimate contact of the liquid (in a very thin film) with the atmosphere and the rock. The initial stages of the disintegration are caused by the action of water in contact with air rather than by that of salts in the water. Colloidal precipitation, which takes place when decomposition of the silicate begins, leads to selective absorption and consequent acidification of the solution, giving rise in turn to further, and probably more intense, disintegration. The process is continuous, gel being continuously precipitated, and further selective absorption taking place. The gel, being irreversible, is not taken up as an emulsion, and can consequently be removed only mechanically.

Comparison with the action of sea-water.—On comparing the action of sea-water on bowlders of similar composition to those attacked by the brines, one finds an undoubtedly real difference in the degree of corrosion. It is, however, a difference in degree, not in process. The evidences of chemical erosion caused by the sea-water are to a large extent removed by mechanical attrition caused by the impact of the waves on the bowlders, and the consequent rolling of the bowlders on the beach. Even in large bowlders, however, where rolling is reduced to a minimum, the evidence of chemical disintegration is small indeed in comparison with that of the bowlders from the salt flats. The relatively small difference in concentration of sodium chloride is not sufficient to account for the difference in chemical activity in the two cases.

Bowlders between high and low watermark are situated similarly to those on the salt flats in one particular—they are in intimate contact with the solution and with the atmosphere. They are differently placed, however, in that they are alternately water-covered and dry to the base. Evaporation does not proceed so far that sodium chloride is precipitated, and films of liquid are not fed over the surface of the bowlder from the base. The initial disintegration of the bowlder is consequently less readily effected, and the acidification of the solution through absorption is to a similar extent retarded.

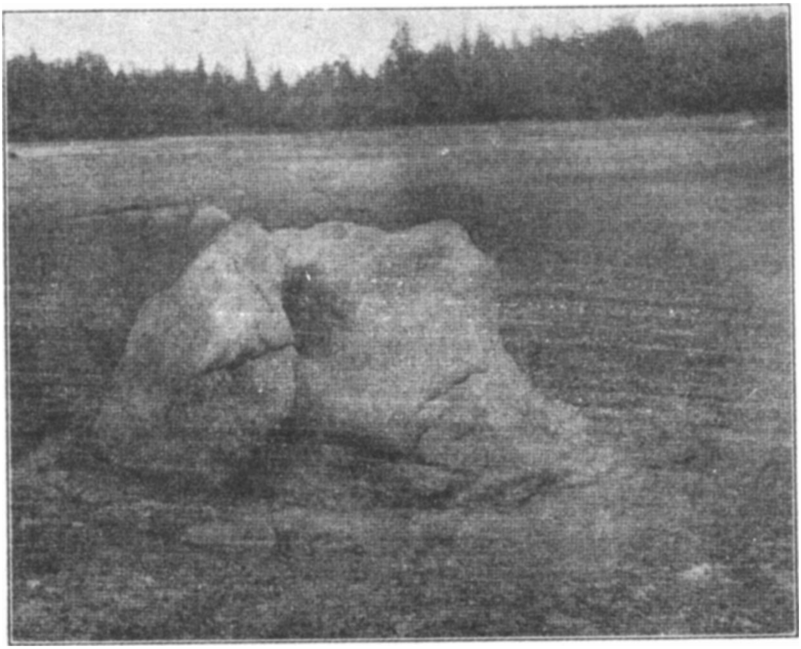

FIG. 3.—Corroded bowlder, salt flat, Pelican Bay, Lake Winnipegosis

While to different physical conditions may be attributed the difference in degree of corrosion of beach bowlders and bowlders of similar type in salt flats, the fact of chemical erosion by sea-water is emphasized by the study of the action of this essentially similar brine. The chemical action of sea-water on igneous rocks between high and low watermark must be much more considerable than is generally believed. The disintegration attributed to mechanical attrition is undoubtedly, in part, at least, chemical. Sea-water under great pressure is apparently a solvent for the volcanic débris which reaches the bottom of the deeper ocean; but the solvent power is intensified by contact with the atmosphere, even at ordinary pressures. Conditions are most suitable when the three phases—solid, liquid, and gas—remain in intimate contact for considerable periods of time. Such is the case where shallow pools of water are imprisoned in the hollows of the rock surfaces when the tide recedes; in these cases evidences of corrosion are very clear.

It would be futile to attempt to compare in intensity the action of sea-water on beach bowlders and that of rain-water impregnated with humus acids from the soil. Data are not available in the field. It must suffice, at this stage, to rank sea-water and acidified rain-water side by side as two potent agents from the chemical, as from the mechanical, standpoint, in the disintegration of rocks.